



Risk-Hedged Approach for Re-routing Air Traffic Under Weather Uncertainty

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Outline

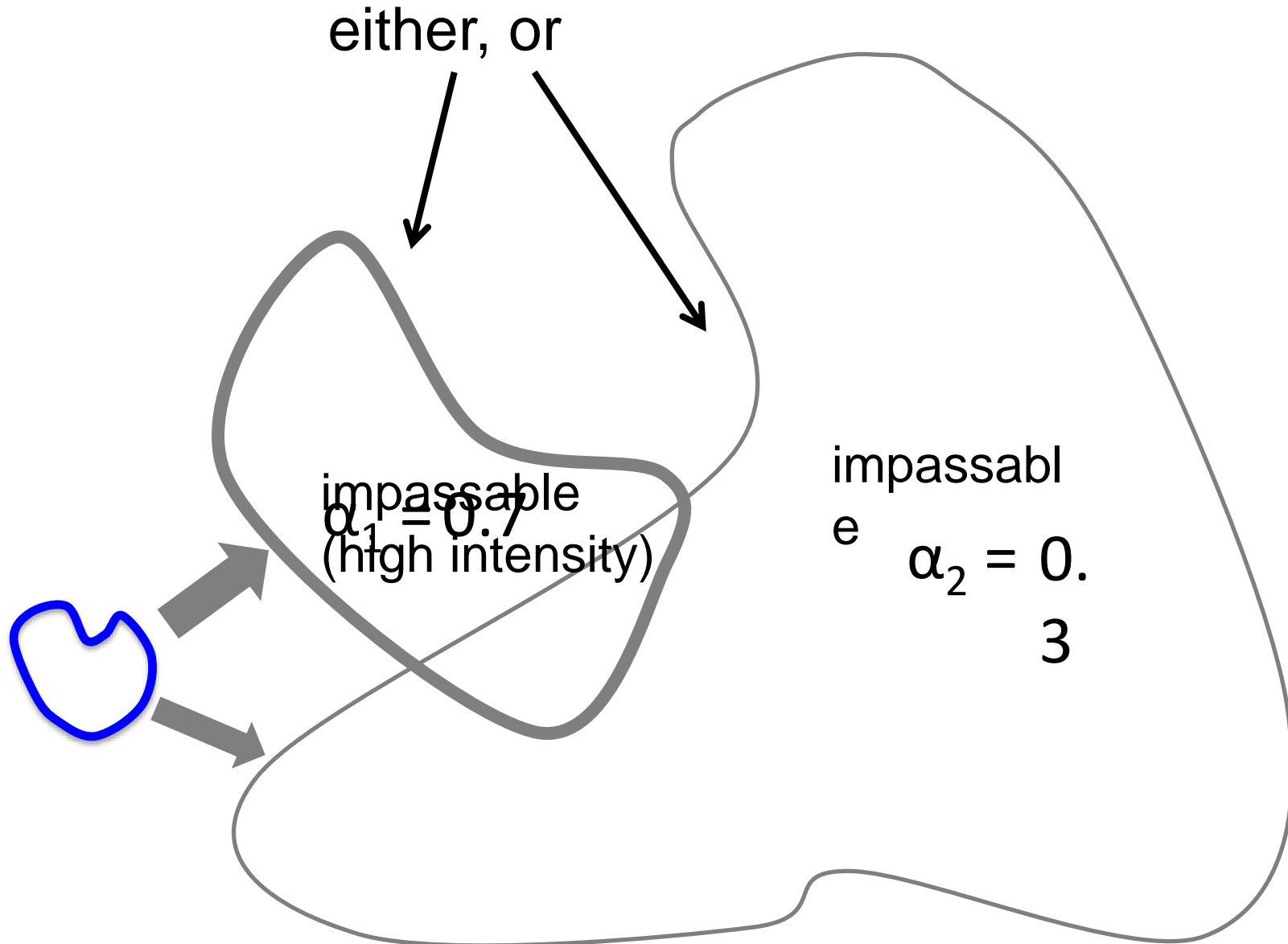
- Background on route planning
- Re-routing options for weather avoidance
- Risk-hedged approach for re-routing
- Example results
- Conclusion

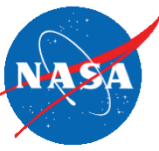


Background

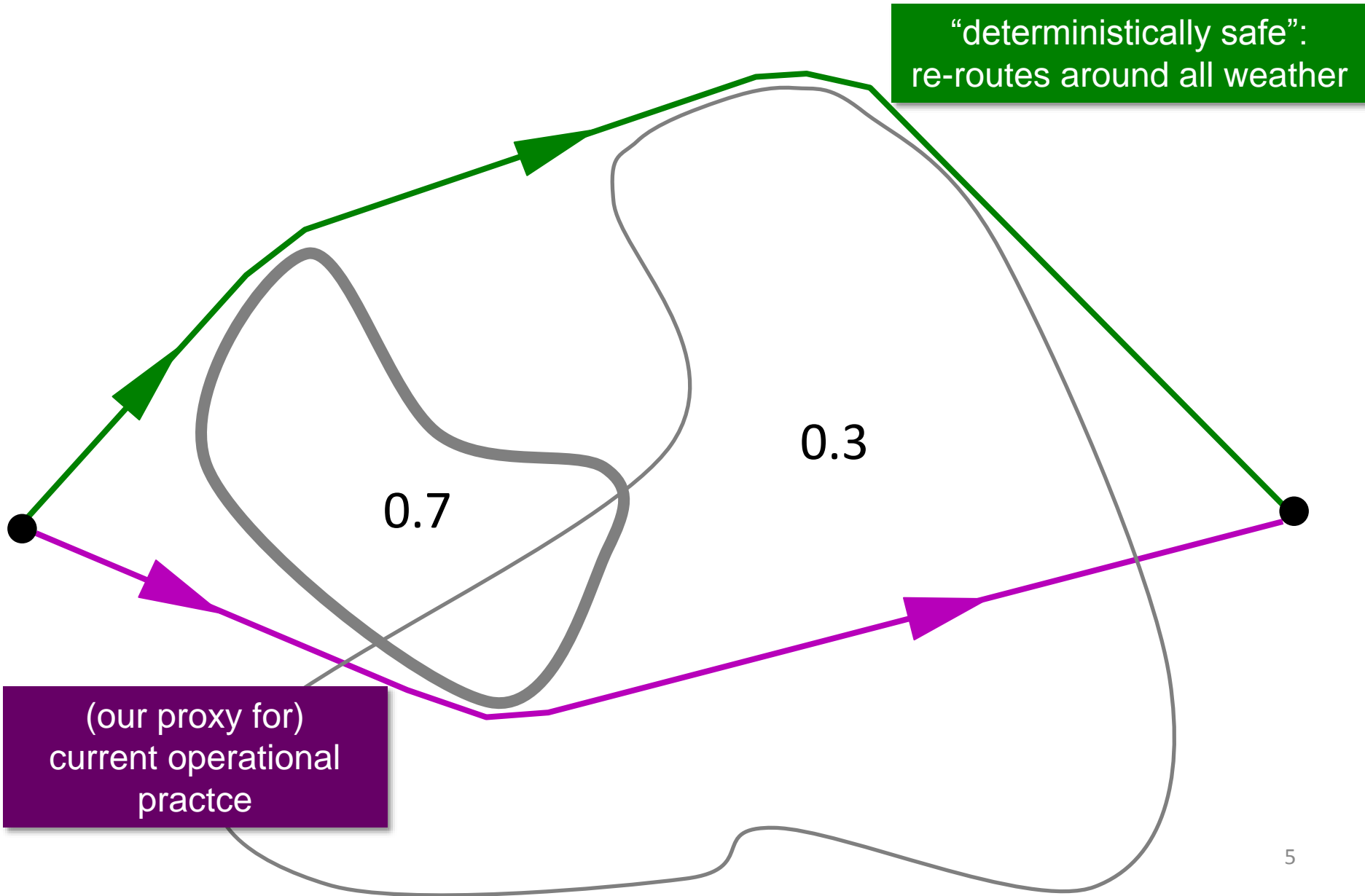
- Flight operators design the routes they wish to fly
- Air traffic service provider designs and implements re-routing around bad weather
- Strategic planning for re-routes around large weather systems is based on multi-hour weather forecasts
- Multi-hour weather forecasts have high uncertainty, but current products typically provide only the most likely instantiation of future weather

Re-routing for Weather Avoidance





Re-routing for Weather Avoidance



Motivation for Risk-Hedging



can incur high flight operation cost

can incur high cost for disruption of traffic operations

Risk-hedged approach:

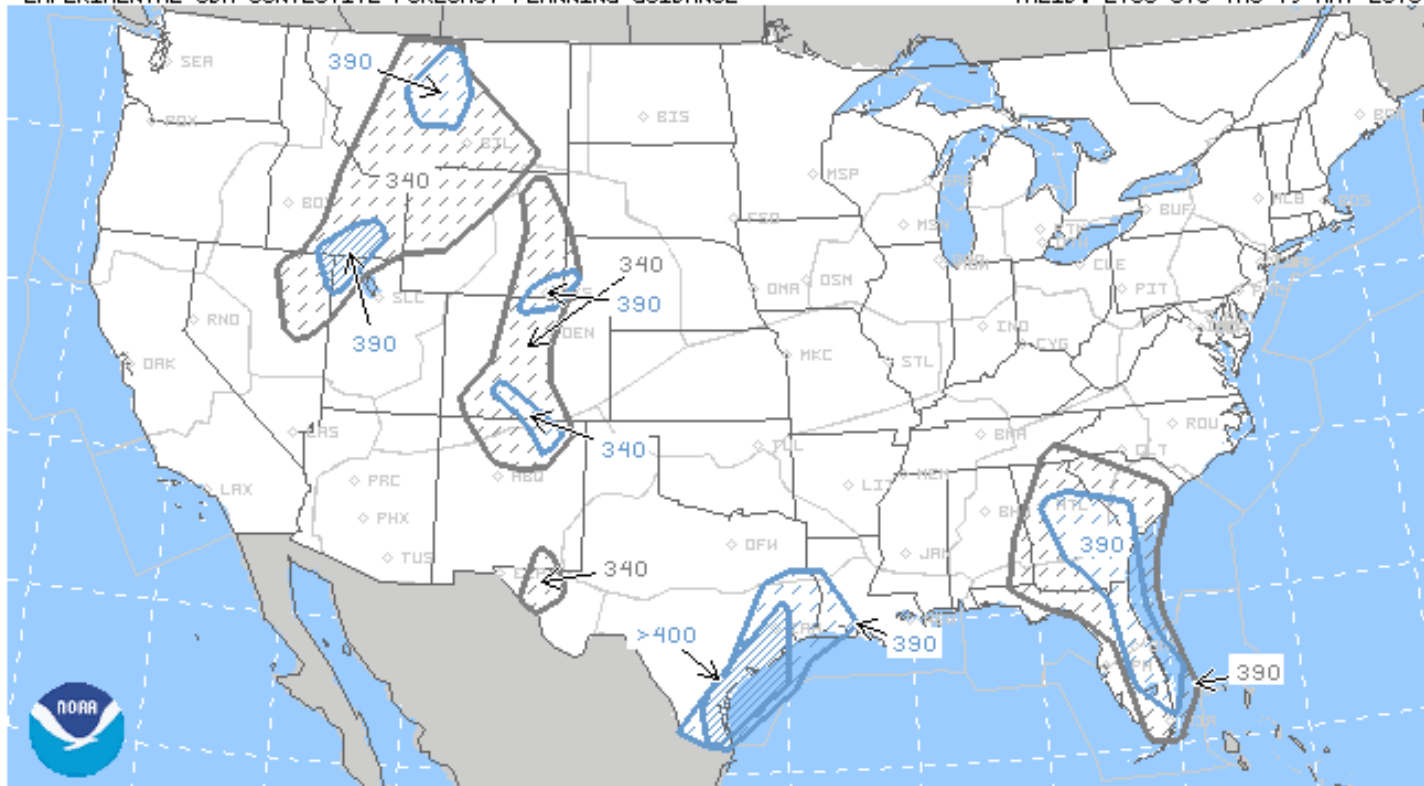
minimize a combination of these two costs (later slide)

- “Risk” refers to risk of disruption caused by tactical re-routing; hence a path has high risk if a large segment lies within a weather instantiation of high likelihood
- Research is far term: assumes ensemble weather forecast with multiple (instantiations + likelihoods)
- CDM (Collaborative Decision Making) Convective Forecast Planning (CCFP) currently provides a rudimentary version of the desired capability

Example CCFP Advisory

EXPERIMENTAL CDM CONVECTIVE FORECAST PLANNING GUIDANCE

VALID: 2100 UTC THU 19 MAY 2016



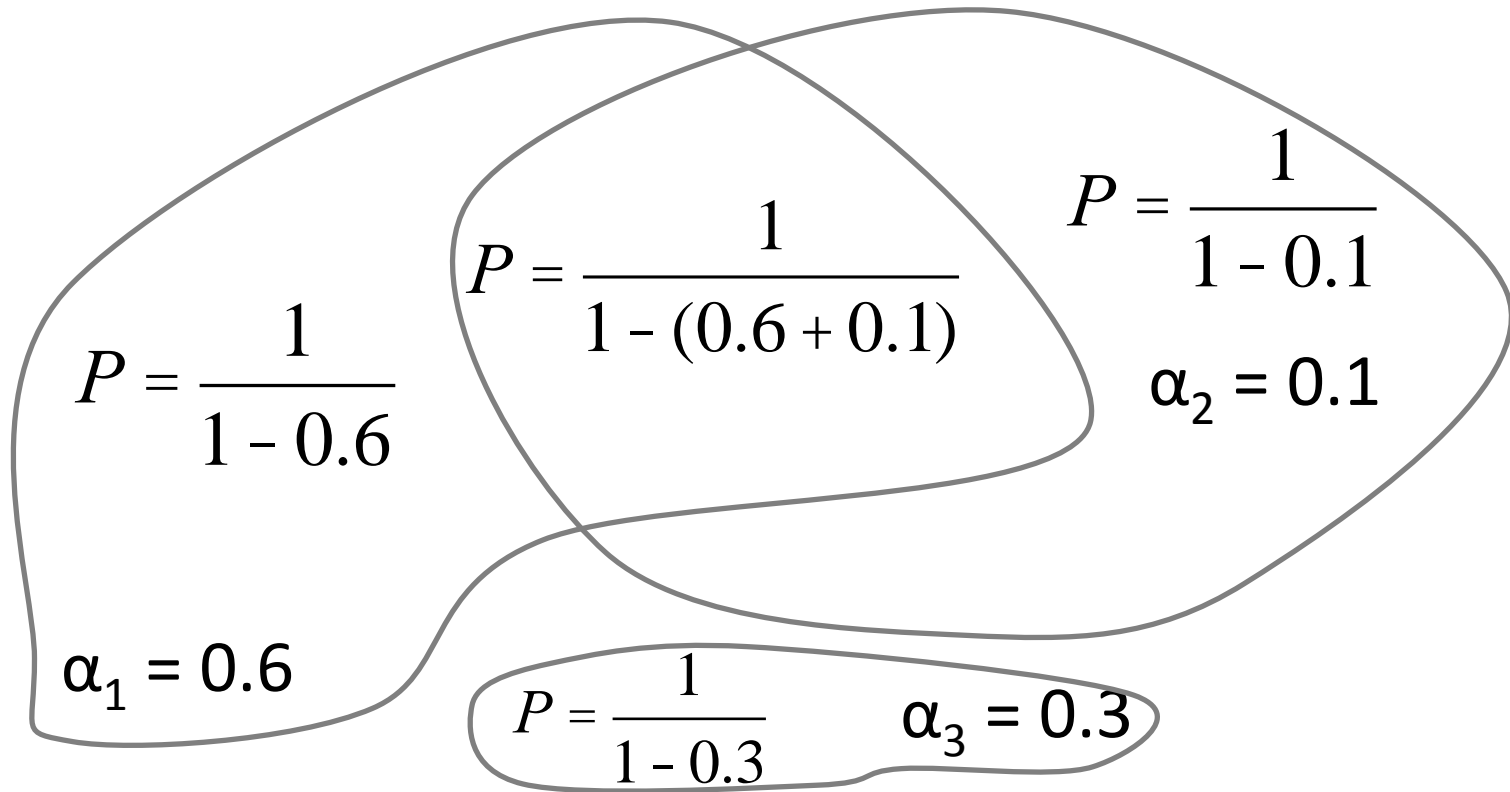
AVIATION WEATHER CENTER (NOAA/NWS/NCEP)

ISSUED: 1900 UTC THU 19 MAY 2016

		CONFIDENCE:		HEIGHT	
		LOW 25-49%	HIGH 50-100%	TOPS: 100's OF FEET MSL	
CONVECTIVE COVERAGE:	SPARSE 25-39%			25000 - 29000	290
	MEDIUM+			30000 - 34000	340
	40-100%			35000 - 39000	390
				40000+	>400

Risk-Adjusted Field

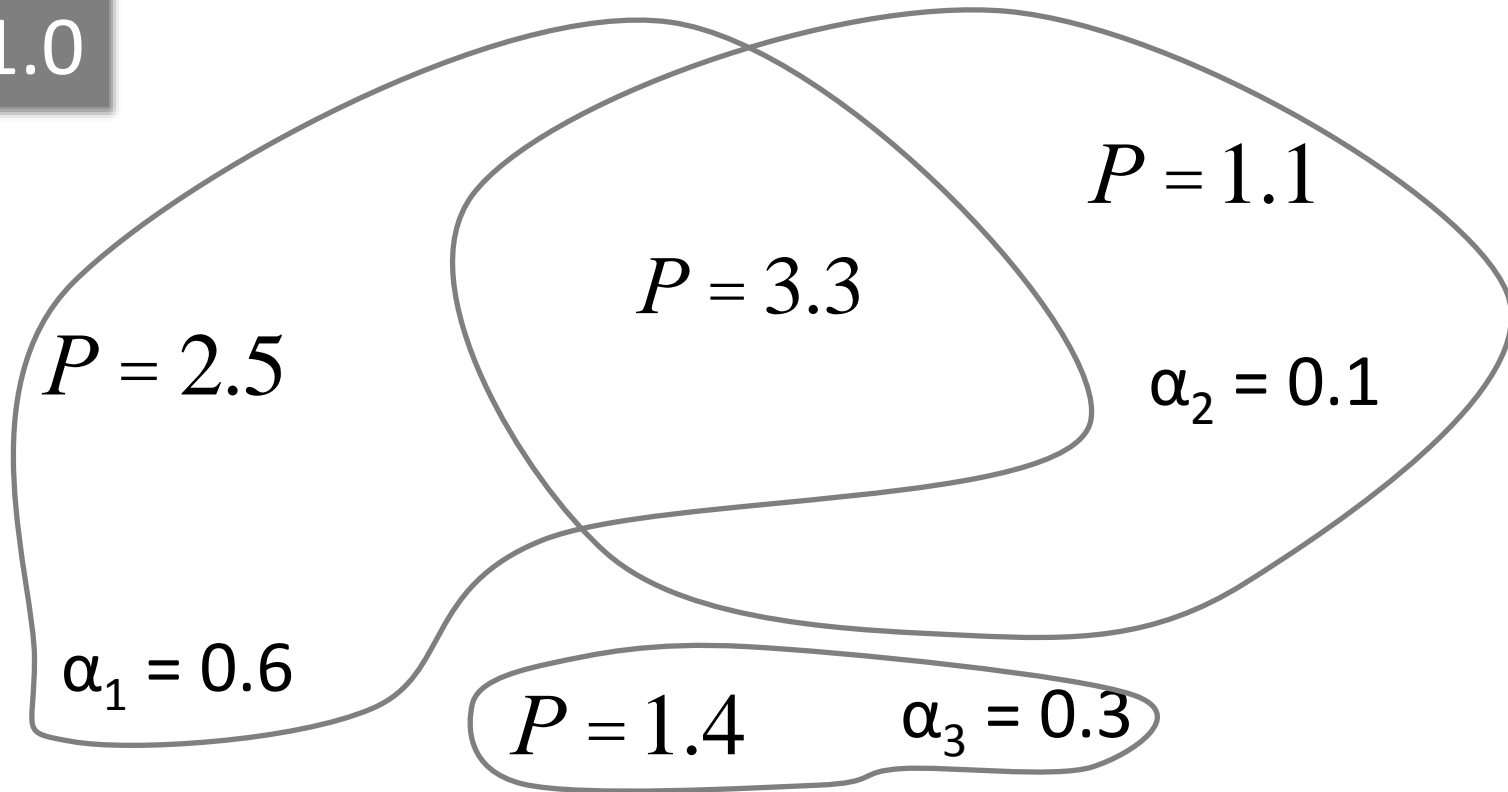
$$P = 1 / (1 - \Sigma \alpha_i)$$



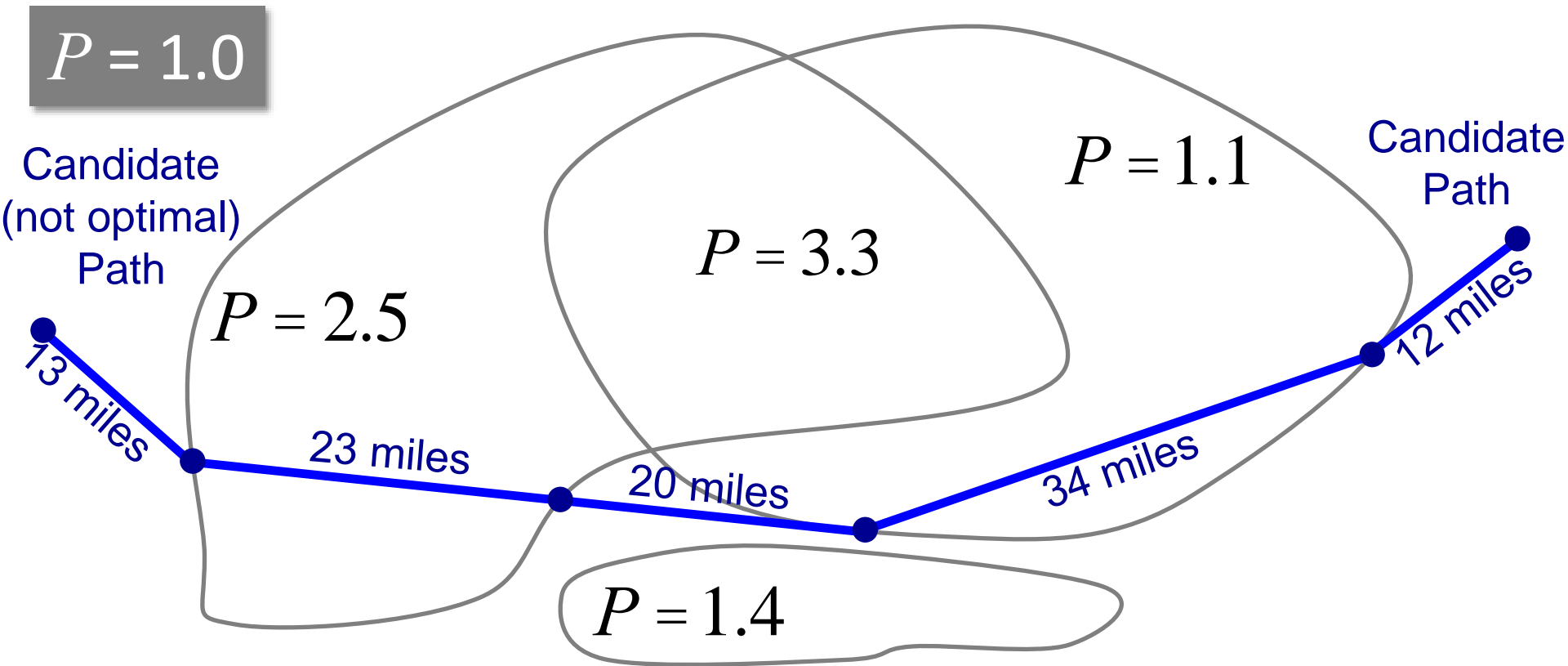
Risk-Adjusted Field

$$P = 1 / (1 - \Sigma \alpha_i)$$

$$P = 1.0$$



Risk-Adjusted Path Length: the minimization objective



$$\text{Risk-adjusted path length} = (1 \times 13 + 2.5 \times 23 + 1 \times 20 + 1.1 \times 34 + 1 \times 12) = 130.9 \text{ miles}$$



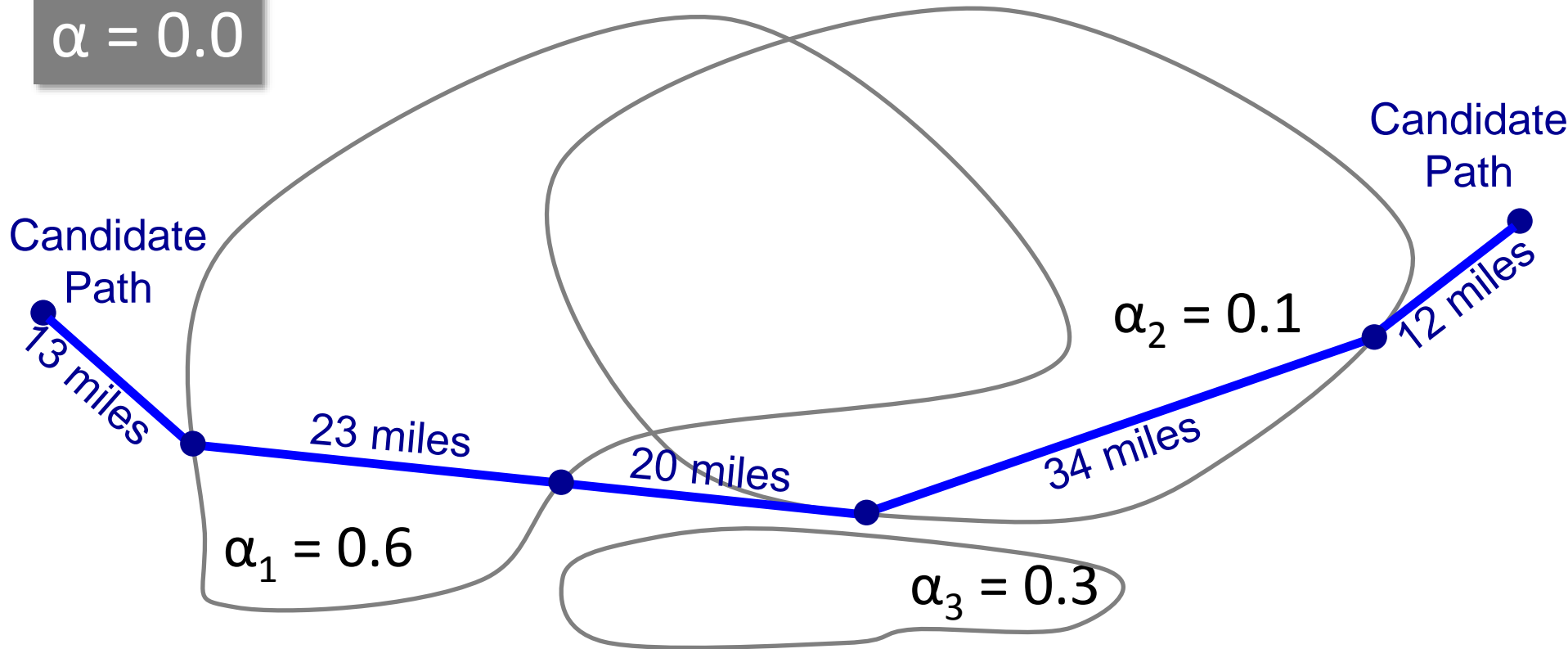
Risk-Hedged Re-routing

- Compute re-routes by minimizing risk-adjusted path length
- Evaluate the computed re-routing using these metrics:
 - Path length (proxy for flight operation cost)
 - Path risk (defined on next slide)



Path Risk: an evaluation metric

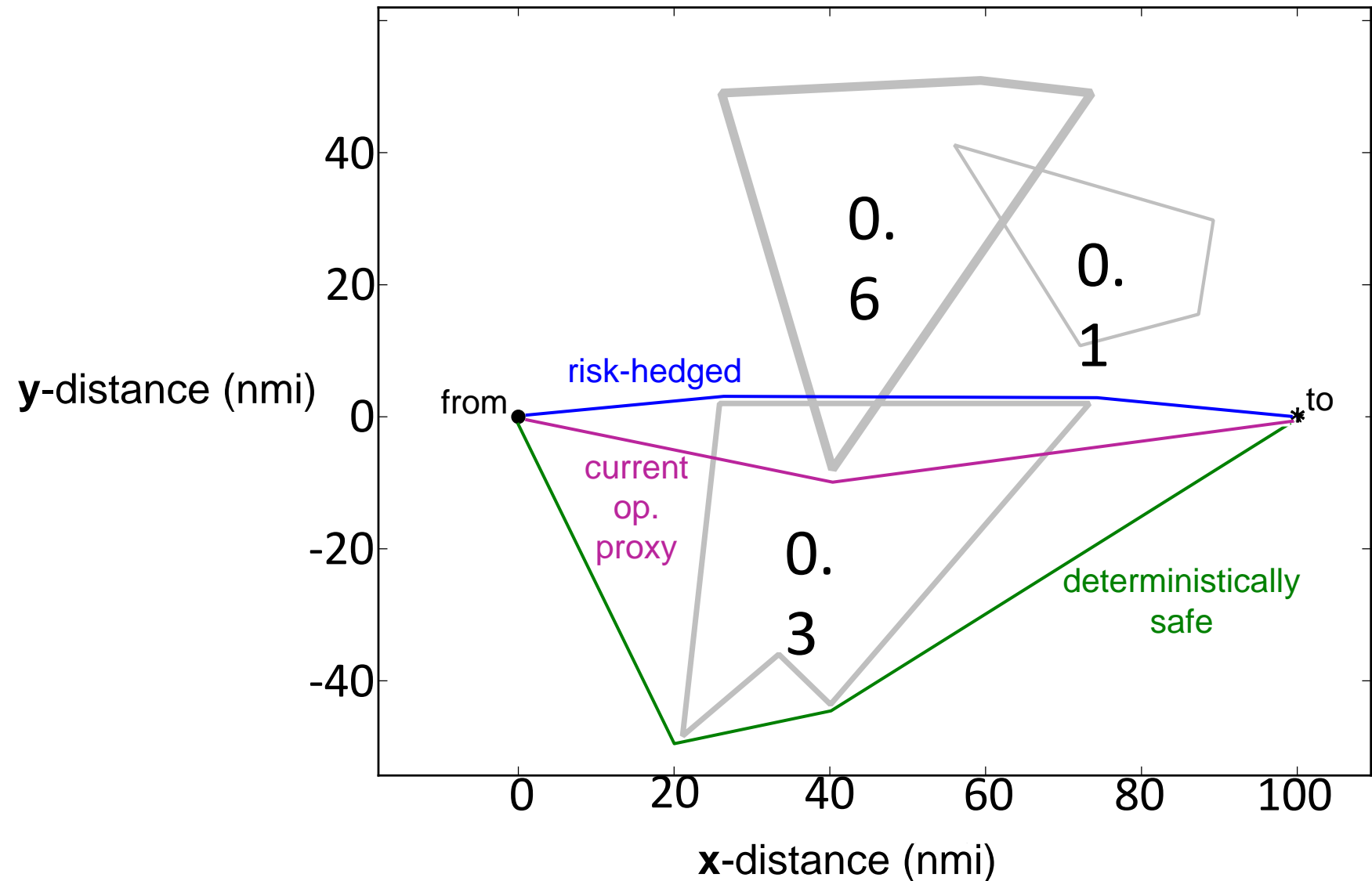
$$\alpha = 0.0$$



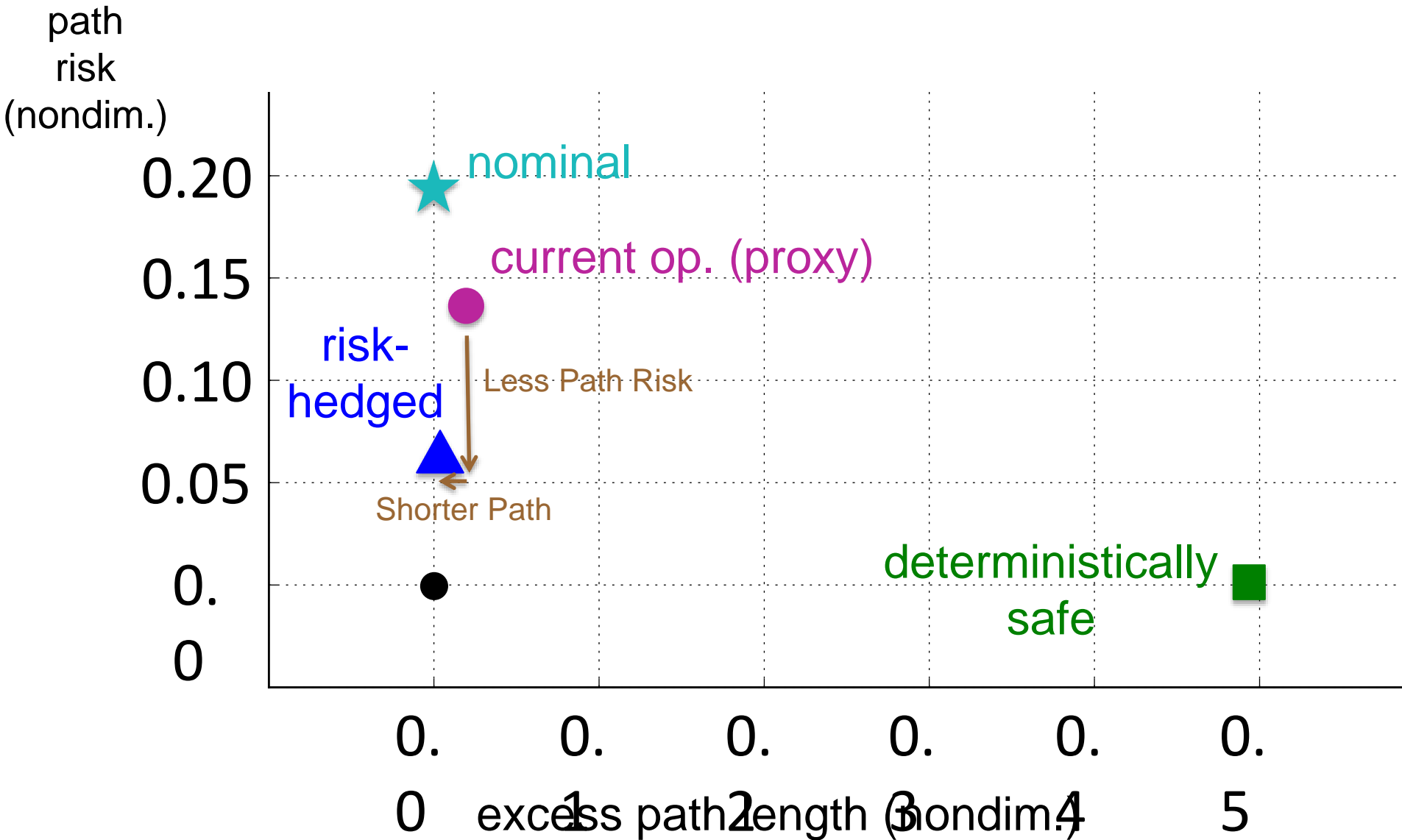
Path Risk =

$$(0 \times 13 + 0.6 \times 23 + 0 \times 20 + 0.1 \times 34 + 0 \times 12) / (13 + 23 + 20 + 34 + 12) = 0.17$$

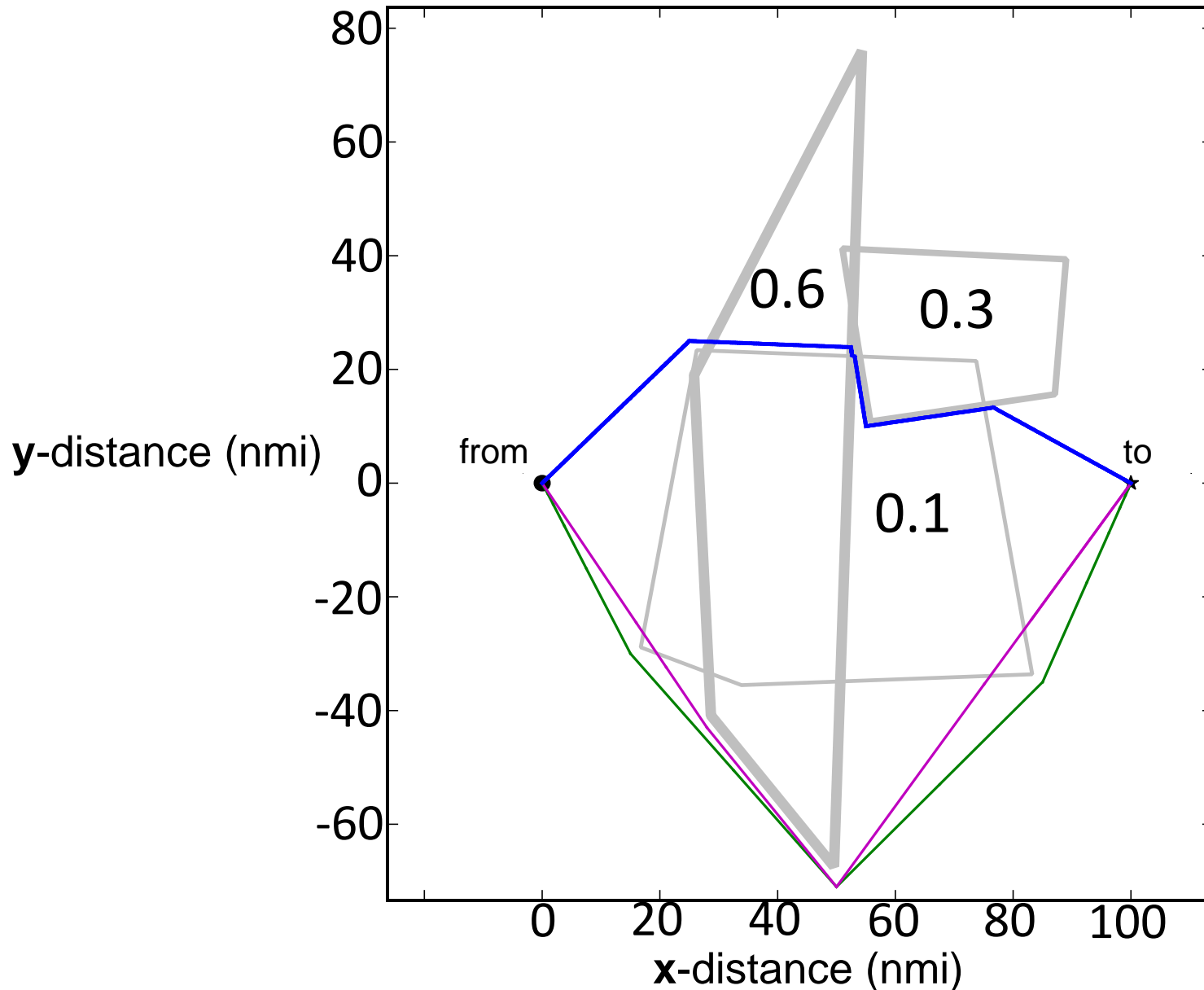
Re-routing Options – Example #1



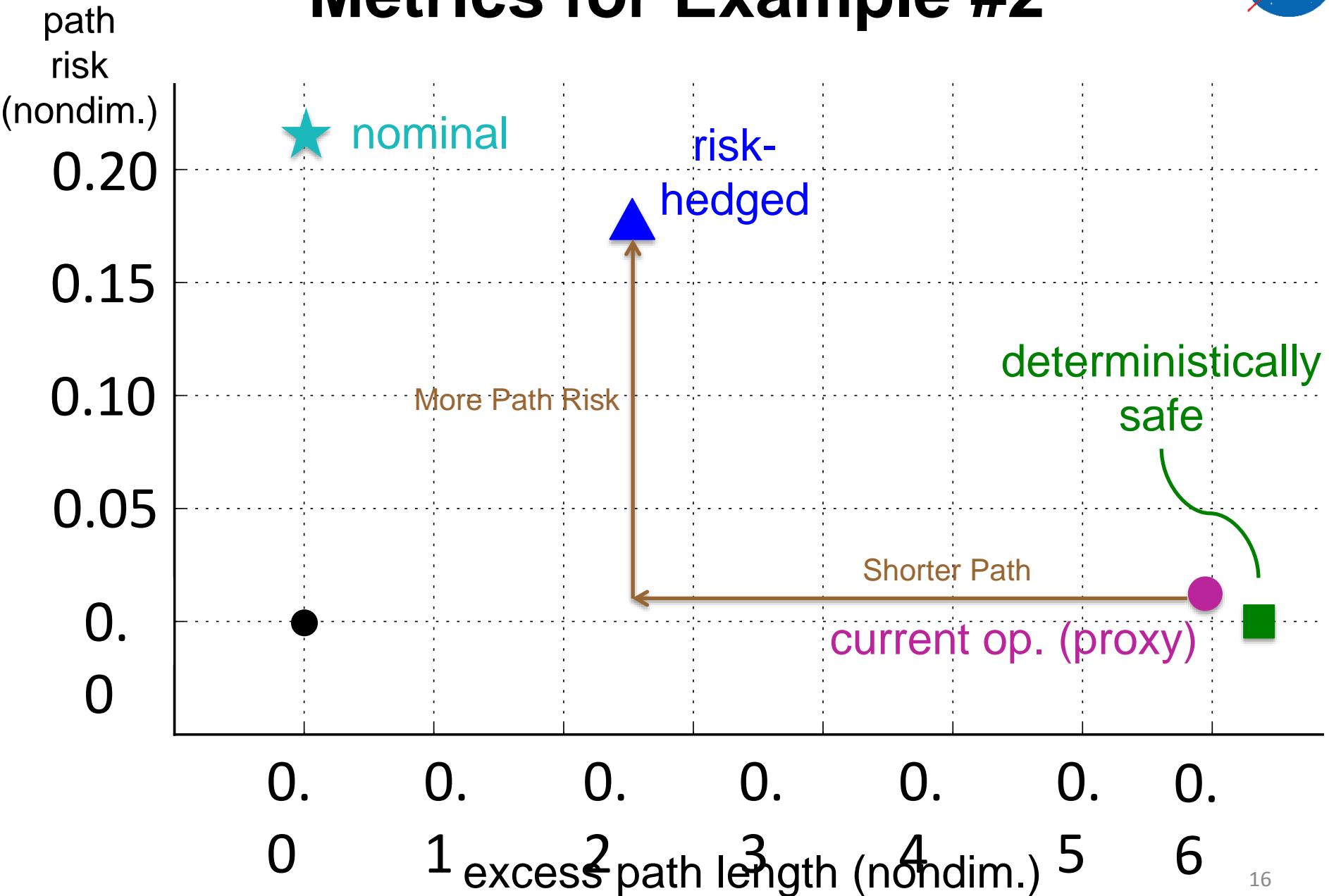
Metrics for Example #1



Re-routing Options – Example #2



Metrics for Example #2



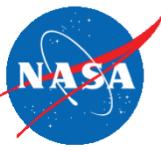


Conclusion

- In some weather avoidance scenarios, the risk-hedged re-routing is shorter and less risky than operational practice
- In other scenarios, risk-hedged re-routing can be:
 - Less risky, but has a longer path
 - More risky, but has a shorter path
- Potential application to re-routing for weather avoidance:
 - Compute risk-hedged path
 - Compare with operational-practice path for risk and path length
 - Choose risk-hedged path if both safer and shorter



Backup Slides



Minimization problem: the Eikonal equation

$$\frac{1}{P(x)} \left| \text{grad} \left(\text{min. cost to endpoint from } x \right) \right| = 1$$

East-bound flows from ZLA, ZAB, ZFW, ZHU are merged and then split into two flows going to DC and NYC airports

